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# Sediment Characteristics of Toroidal Volume Search Sonar (TVSS) Test Sites Off Panama City, Florida

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**13. ABSTRACT** *(Maximum 200 words)*

Acoustic tests were conducted at two sites off Panama City, FL, using the Toroidal Volume Search Sonar (TVSS) which is under development at the Naval Surface Warfare Center's Coastal Systems Station. Inverse modeling of the resultant TVSS acoustic data, using the BOGGART Backscatter model developed by the Applied Research Laboratory at the University of Texas, indicates differences between the sediment physical properties and/or bottom roughness of the sites. Neither seafloor roughness (microtopography) measurements nor bottom samples for sediment properties measurements were obtained during the TVSS tests. Therefore, the purpose of this report is to provide documented information as to the seafloor and sediment characteristics of the two test sites for use in evaluating the potential of the TVSS to classify sediments. The information obtained is consistent with the inverse modeling results, i.e., differences in bottom roughness and sediment physical properties do indeed exist at the two test sites. Therefore, upon initial analysis, the concept of using the TVSS as a bottom sediment classifier when it is operating in its designed role of minefield reconnaissance appears viable. However, this concept should be tested over a variety of seafloors that have been thoroughly characterized according to microtopography and sediment physical properties.

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mine countermeasures, sonar performance, sediment classification, bathymetry, TVSS, MTEDS, ASTER, sediment properties, bottom acoustic mapping

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BACKGROUND:

During the period 19 October through 20 November 1994, High Area Rate Reconnaissance (HARR) tests were conducted in the Gulf of Mexico off Panama City, Florida using the Toroidal Volume Search Sonar (TVSS) that is being developed at the Naval Surface Warfare Center's Coastal Systems Station. The tests were conducted at two sites (Fig. 1) in water depths of about 100 feet (shallow field) and 600 feet (deep field). Acoustic data collected by the TVSS at each site was used as input to BOGGART (Bottom Grain Gas and Roughness Technique), a model developed by the Applied Research Laboratory at the University of Texas for predicting acoustic backscatter from marine sediments (Boyle and Chotiros, 1996). Inverse modeling of the backscatter data produces results consistent with differences between the sediment physical properties and/or bottom roughness (microtopography) at the two sites (Chotiros, 1997). The purpose of this report is to document any differences in the sediment character at these sites for use in evaluating the potential of the TVSS as a bottom sediment classifier.

SITE CHARACTERIZATION DATA:

Bottom samples were not collected for site characterizations during or after the tests. Perusal of the literature reveals, furthermore, that no bottom samples have ever been taken within the bounds of either site (Fig. 1). Adequate information does exist, however, regarding regional trends that can be extrapolated to each site with reasonable confidence. The information is mainly in the form of figures or tables that summarize various sediment property measurements.

DATA INTERPRETATION:

A regional overview of the surficial sediments of the Mississippi, Alabama, and Florida continental shelf (Fig. 2) shows that the sediments at the shallow test site consists of at least 90% sand; whereas, the sand content is much lower (less than 50%) at the deeper test site. These general observations are substantiated by bottom samples collected along transect (line) 10 in Figure 3 (note that transect 10 nearly passes through the deep-water site). Figure 4 shows profiles of (A) water depth and (B) percent sand along sampling line 10. Three points are noteworthy: (1) the sand content decreases sharply at 300 feet (50 fm) from virtually 100% in shallow water to about 20% at the deep water site, which is consistent with

the contours in Figure 2; (2) in general, the variations in sand content are much smaller in the deep water areas (>50 fm) than in the shallow water areas; (3) profile A in Figure 4 shows that small-scale bottom roughness is associated with the continental shelf, particularly the inner shelf, whereas the continental slope is comparatively smooth. Side-scan sonar imagery (Fleischer, personal communication) tends to support this observation.

A map of sediment distribution for the continental margin of the Florida panhandle (Fig. 5) shows that the shallow site is located within an extensive sand sheet (Cape San Blas Sand Facies) that covers the open shelf out to about the 100 m contour. In contrast, the deep site is situated on the continental slope in a marl/chalk facies (West Florida Lime-Mud Facies) that consists largely of clay minerals (mainly smectite) and fine grained carbonate material (mostly coccoliths). Figure 6A shows, however, that the West Florida lime-Mud Facies is bimodal. Modal mixtures at the centers of the two modes in Figure 6A are; 4% terrigenous sand, 21% carbonate sand, and 75% silt and clay (fine mode), and 10% terrigenous sand, 50% carbonate sand, and 40% silt and clay (coarse mode). The sands in both modes consists principally of foraminifera tests.

Sediments within the Cape San Blas Sand Facies (Fig. 6B) are predominantly terrestrial (quartz) sands, with carbonate sands generally less than 25 percent (Doyle and Sparks, 1980). Coarse sands and gravels consisting of 10-90% shell fragments also occur within this facies. Ludwick (1964) notes that along sampling line 10 (Figs. 3 and 5) there are 29 occurrences of shell sands (>25% shell material) over a distance of 13 miles.

Figure 7 shows that the median grain size for the West Florida Lime-Mud Facies is 0.05 mm (4.25 phi), i.e., a coarse silt that is about 45% sand and 55% silt/clay. This grain size distribution fits the coarse modal mixture shown in Figure 6A. It is important to note, however, that this distribution is based on only 4 samples and may not be an accurate representation of the facies. Indeed, it will be shown later that the fine modal mixture in Figure 6A is more representative of the sediments at the deep site. The Cape San Blas Facies, on the other hand, has virtually no fine fraction. The distribution of grains (Fig. 7) ranges from very fine sand (0.1 mm or 3.25 phi) to coarse sand (0.6 mm or 0.75 phi) with a median grain size of 0.17 mm (2.5 phi) or fine sand.

The area off Panama City, Florida was systematically sampled in 1972 by McLeroy. Figure 8 shows that stations 40 and 44 lie very close to the TVSS test sites. Table A1 shows, in turn, that the sediments at station 44 (shallow site) consist of 93% sand-size material, which is in agreement with the contours shown in Figure 2 and with profile B in Figure 4. The low values measured for void ratio, porosity, and water content are consistent with the high sand content. In contrast, the sediments at station 40 (deep site) consist of only 21% sand (and 1% gravel); hence, a fine fraction of 78% (and higher values for void ratio, porosity, and water content). A sand content of 21% at the deep site is consist with profile B in Figure 4. Moreover, 21% sand and 78% silt/clay is nearly identical with the "fine" modal mixture in Figure 6A. Thus, the sediment distribution indicated by Figures 6B and 7 (i.e., predominantly coarse grained) is probably not indicative of the sediments at the deep test site. Indeed, when viewed in a regional context (Fig. 9), it is apparent that most of the area encompassed by the deep site falls within the contour defining an area with at least 80% fine-grained sediment. The shallow site, in contrast, falls well within the contour bounding sediments with less than 6% fine-grained material.

Based on his measurements, McLeroy (1972) derived a relationship between reflection loss and water content (Fig. 10). Chotiros (1997) presents a similar relationship, but for porosity rather than water content (Fig. 11A). In order to compare the two relationships, the water contents in Figure 10 were converted to porosity estimates using a grain density of 2.13 and the tables of Lambert and Bennett (1972). The grain density (2.13) is an average value derived from all the sediments samples listed in Table 1A with a fine fraction of 70% or greater. Similarly, these same samples have an average porosity of approximately 65%. This porosity corresponds to a reflection loss of -20.5 dB in Figure 10, which compares favorably with -16.5 dB in Fig. 11A.

There are uncertainties associated with Figure 10 that should be noted: (1) It is assumed from his values (e.g., -10, -20, etc.) that McLeroy means reflection loss and not reflection coefficient. Thus, Figure 10 has been modified to read Reflection Loss; (2) based on his values, it appears certain that McLeroy has the column headings "bulk density" and "specific gravity" reversed in Table 1A. Accordingly, the headings have been placed above the proper list of values in Table 1A of this report; and (3) the two regression lines through the data are visual estimates.

Chotiros (1997) also relates reflection loss to mean grain size (Fig. 11B). Assuming that the mean and median are roughly equivalent parameters, a median grain size of 4.25 phi (from Figure 7) corresponds to a reflection loss of 14 dB in Figure 11B. As noted, however, the deep site is probably better represented by the fine modal mixture in Figure 6A. This mixture is reasonably represented in Hamilton et al. (1982; Table 1) by an average calcareous silty clay consisting of 17% sand and 73% silt/clay. The mean grain size for such a sediment is 7.89 phi which, in Figure 11B, results in a predicted reflection loss of -20.5 dB, i.e., exactly the same reflection loss derived in Figure 10.

## CONCLUSIONS:

Modeling of acoustic backscatter using the BOGGART scattering model indicates that the bottom returns of TVSS signals are sensitive to either seafloor microtopography, sediment physical properties, or both. Inverse modeling of the backscatter data suggests differences between the physical properties of the two sites. While neither bottom roughness nor sediment properties measurements were made at the sites to support this observation, site characterizations based on published information confirm that the sediment parameters (e.g., grain size, porosity, water content, grain density) of the two sites differ substantially in value. Predictions of reflection loss versus porosity and mean grain size derived from BOGGART compare well with similar results based on sediment and acoustic measurements from the shelf and slope areas around the TVSS sites. These results suggest that the TVSS may be an effective tool for rapid, bottom sediment classification. However, the TVSS bottom classifier concept should be tested over a wide range of seafloor materials and scales of bottom roughness.

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Doyle, L. J. and Sparks, T. N., 1980. Sediments of the Mississippi, Alabama, and Florida (MAFLA) continental shelf. J. Sediment. Pet., 50, 905-916.

Hamilton, E. D., et al. 1982. Acoustic and related properties of calcareous deep-sea sediments. J. Sediment. Pet., 52, 733-753.

Lambert, D. H. and Bennett, R. H., 1972. Tables for determining porosity of deep-sea sediments from water content and average grain density measurements. NOAA Tech. Mem. ERL AOML-17, 50 p.

Ludwick, J. C., 1964. Sediments in northeastern Gulf of Mexico. In: R. L. Miller (Ed.), Papers in Marine Geology, Shepard Commemorative volume. MacMillan, N. Y., 204-238.

McLeroy, E. G., 1972. Measurement and correlation of acoustic reflection and sediment properties off Panama City, Florida. Naval Coastal Systems Laboratory, Informal Report NCSL 112-72, 20 p.

FIGURES.

1. Bathymetric contour chart of the continental shelf and slope area off the Florida panhandle. Locations of TVSS test site areas are shown by boxes (contours are in fathoms).

2. Contours showing average percent sand in the surficial sediments of the continental shelf and slope off the Florida panhandle. Crosses (west of Cape San Blas) mark the locations of the TVSS test sites shown in Figure 1 (from Doyle and Sparks, 1980).

3. Transects along which bottom samples were collected and reported on in Ludwick (1964). Crosses near transect (line) 10 mark the locations of the TVSS test sites (from Ludwick, 1964).

4. Profiles showing variations in (A) water depth and (B) percent sand along transect (line) 10 shown in Figure 3. The dots making up profile B represent bottom dredge samples taken at quarter-mile intervals. The vertical line marks the location of the deep-water site on each profile (from Ludwick, 1964).

5. Sediment distribution map showing the predominant surficial sediment type encountered along the sampling transects shown in Figure 3. Crosses mark the locations of the TVSS test sites (from Ludwick, 1964) .

6. Ternary diagrams showing the textural and compositional make-up of the (A) Western Florida Lime-Mud Facies (deep TVSS test site) and (B) Cape San Blas Sand Facies (shallow TVSS test site). The contours represent the frequency distribution of the samples, i.e., approximately 95% of the samples fall within the interior, cross-hatched area; whereas roughly 5% fall within the lined area (from Ludwick, 1964).

7. Average cumulative grain-size distribution curves (from Ludwick, 1964) of the sediment types shown in Figure 5. The TVSS deep water and shallow water test sites are represented by the Western Florida Lime-Mud Facies curve (5B) and the Cape San Blas Sand Facies curve ((6B), respectively (curves are indicated by *).

8. Numbered bottom sample locations on the continental shelf and slope off the Florida panhandle. TVSS test sites areas are delineated by the boxes (from McLeroy, 1972).

9. Contours of percent silt/clay (recontoured from McLeroy, 1972) based on the analyses of sample taken at the locations shown in Figure 8. TVSS test sites areas are delineated by the boxes (from McLeroy, 1972).

10. Predicted reflection loss versus water content (from McLeroy, 1972). Estimates of porosity are given above the water contents (see text for method used to derive the porosities). Figure has been modified to read reflection loss rather than reflection coefficient (see text for justification).

11. Predicted reflection loss versus (A) porosity, and (B) mean grain size (from Chotiros, 1997).

TABLE

A1. Acoustic and sediment measurements for samples 40 and 41 (see Figure 8 for locations) which fall near the deep and shallow TVSS test site areas, respectively (from McLeroy, 1972).

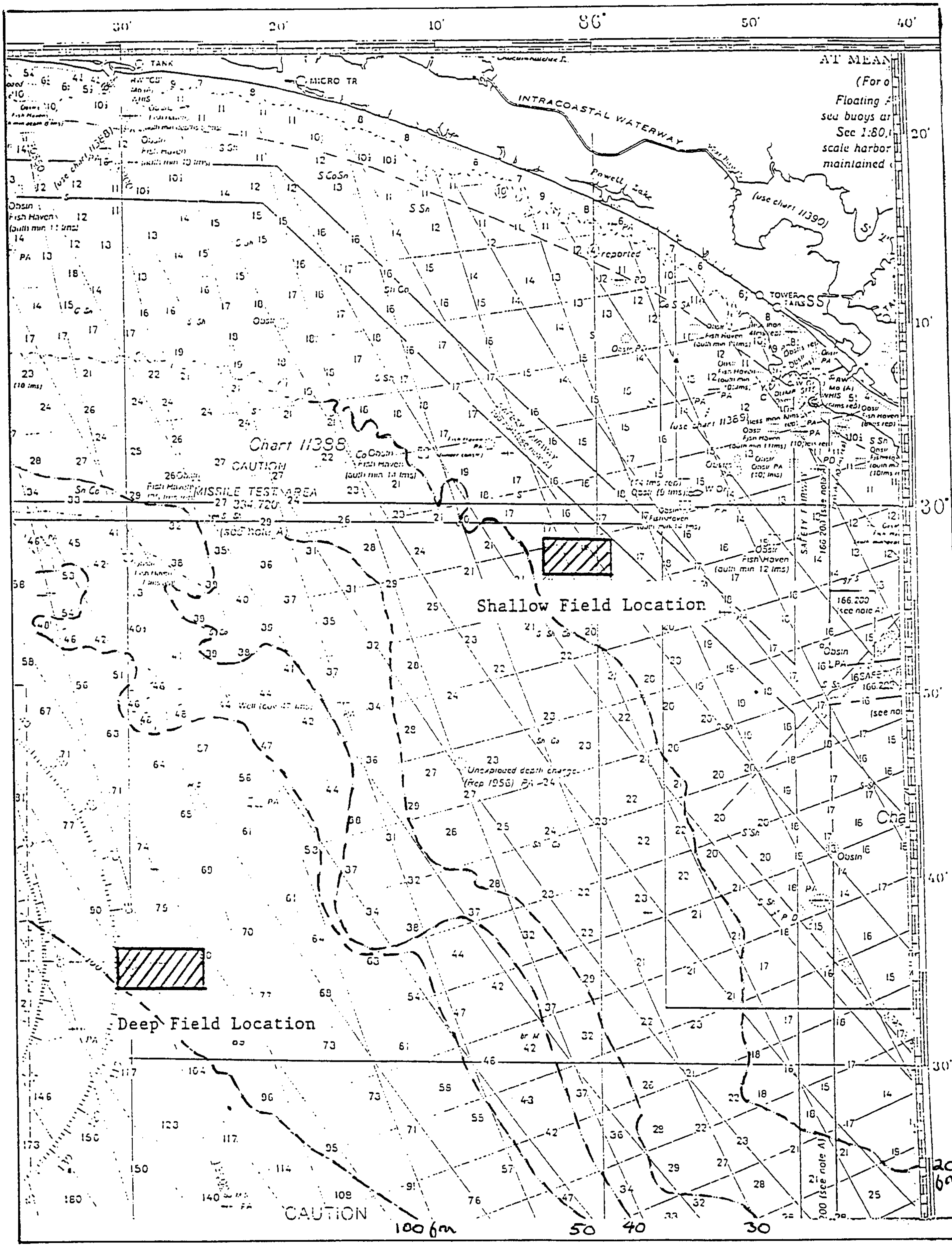

30'
20'
10'
86°
50'
40'
INTRACOASTAL WATERWAY
Powell Lake
MICRO TR
TANK
(use chart 11390)
Chart 11398
CAUTION
MISSILE TEST AREA
SAFETY FAIRWAY
Shallow Field Location
Deep Field Location
Unexploded depth charge (Rep 1956) PA
CAUTION
100 fm
50
40
30
20 fm

Fig. 1

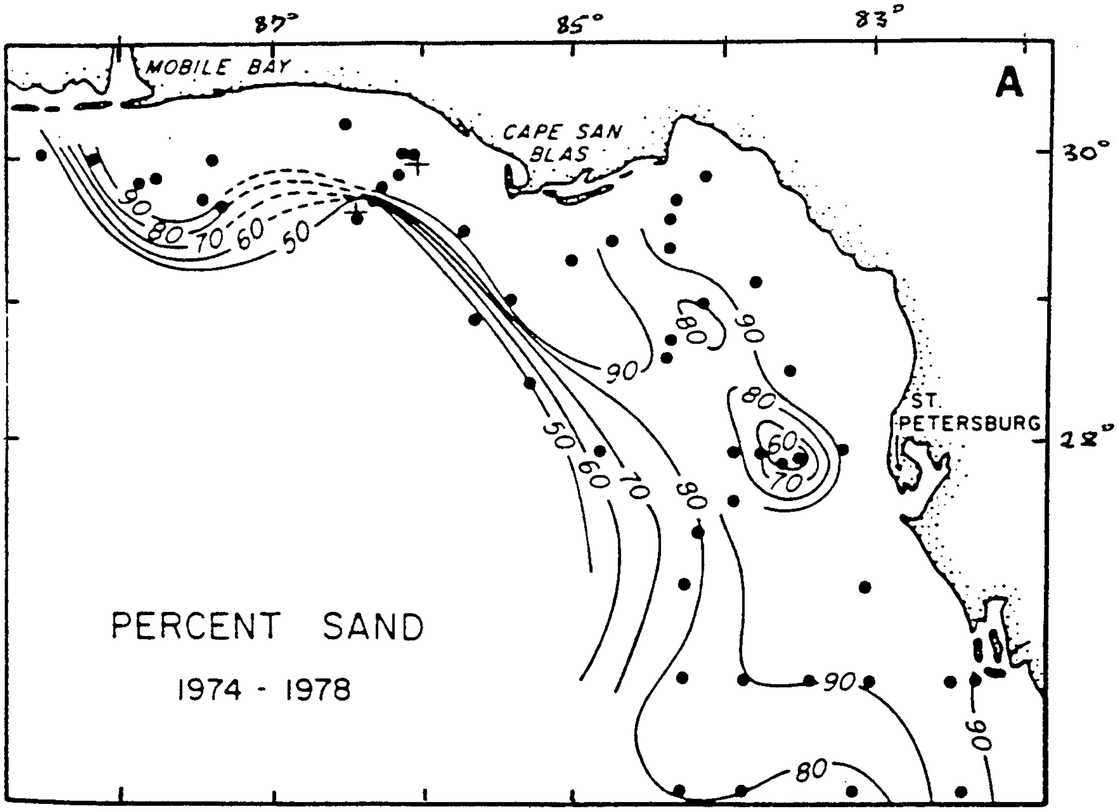

87°
85°
83°
MOBILE BAY
A
CAPE SAN BLAS
30°
ST. PETERSBURG
28°
PERCENT SAND
1974 - 1978

Fig. 2

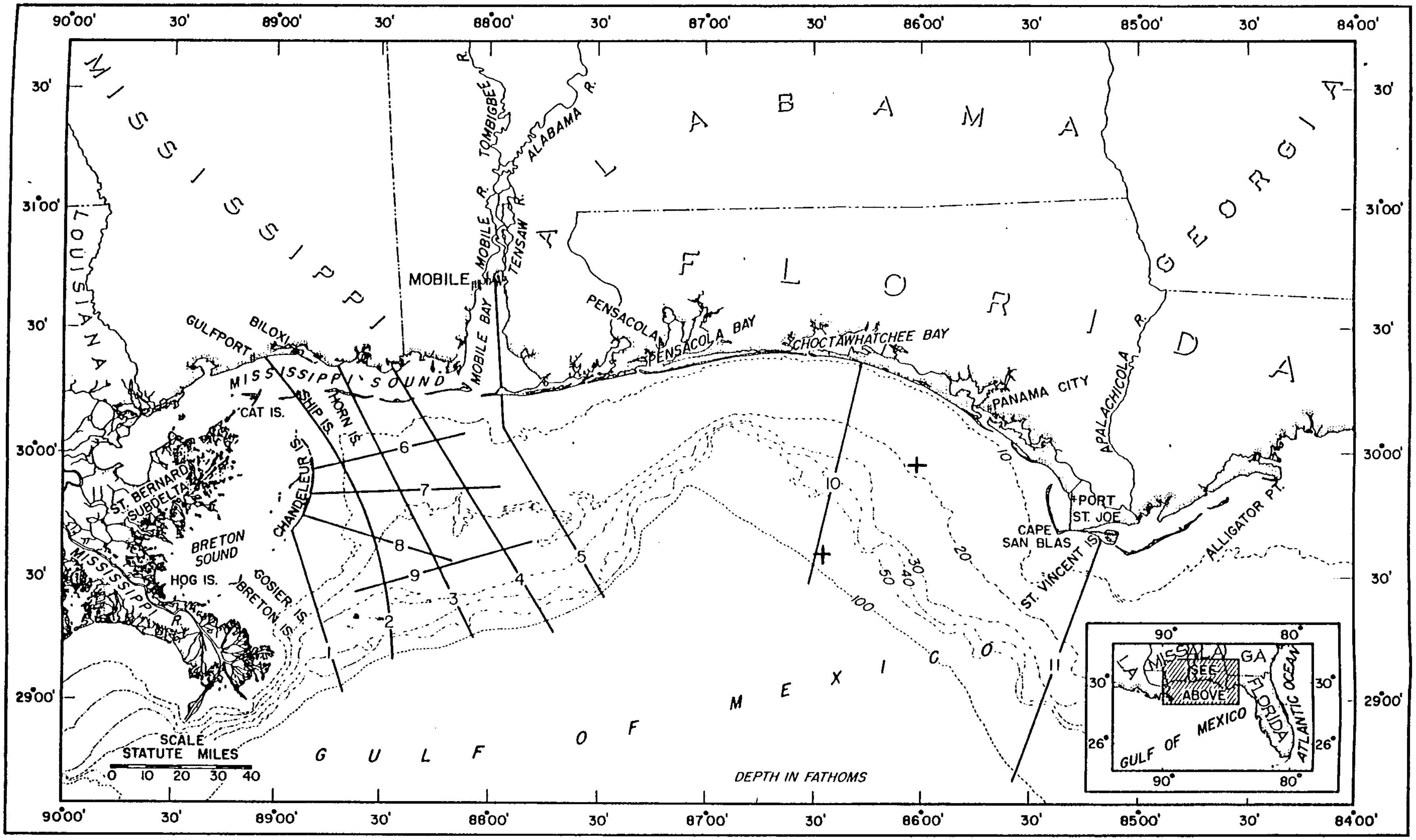

MISSISSIPPI
ALABAMA
FLORIDA
GEORGIA
LOUISIANA
MOBILE
GULFPORT
BILOXI
MISSISSIPPI SOUND
CAT IS.
SHIP IS.
HORN IS.
CHANDELEUR IS.
ST. BERNARD SUBDELTA
BRETON SOUND
HOG IS.
GOSIER IS.
BRETON IS.
MISSISSIPPI R.
TOMBIGBEE R.
ALABAMA R.
MOBILE R.
TENSAW R.
MOBILE BAY
PENSACOLA
PENSACOLA BAY
CHOCTAWHATCHEE BAY
PANAMA CITY
APALACHICOLA R.
PORT ST. JOE
CAPE SAN BLAS
ST. VINCENT IS.
ALLIGATOR PT.
GULF OF MEXICO
DEPTH IN FATHOMS
SCALE
STATUTE MILES
0 10 20 30 40
SEE ABOVE
LA MISS ALA GA FLORIDA
ATLANTIC OCEAN

Fig. 3

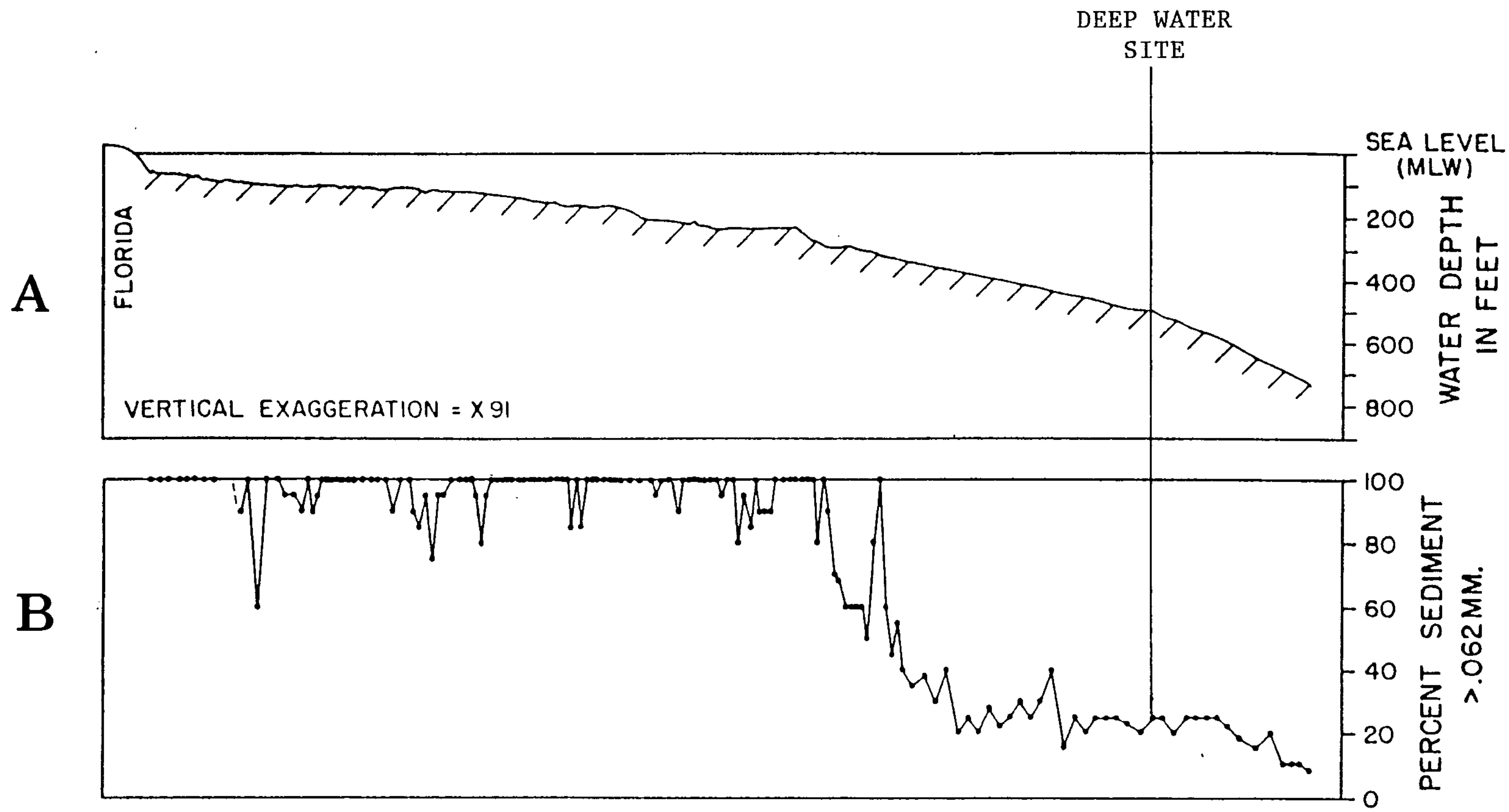
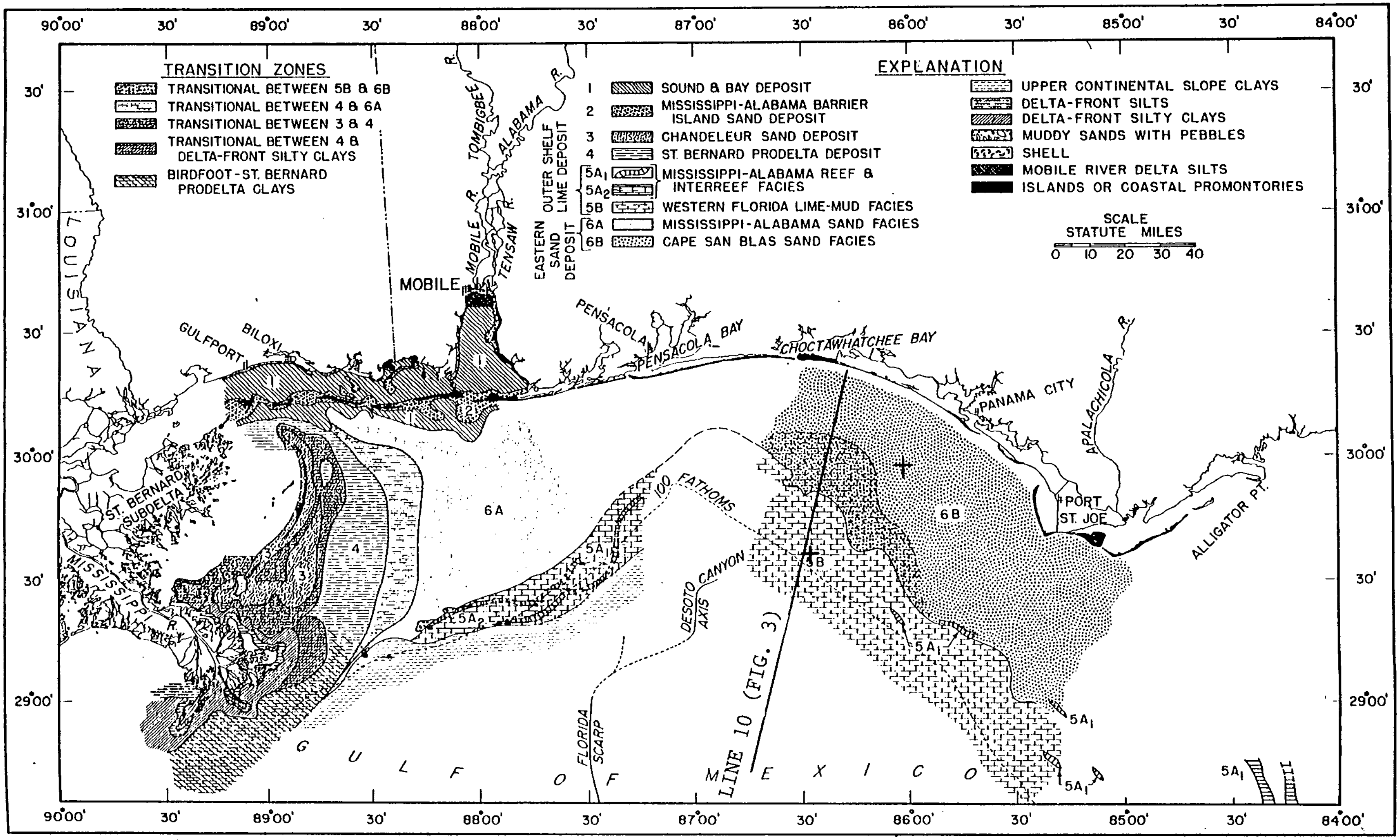

DEEP WATER
SITE
A
FLORIDA
VERTICAL EXAGGERATION = X 91
SEA LEVEL
(MLW)
200
400
600
800
WATER DEPTH
IN FEET
B
100
80
60
40
20
0
PERCENT SEDIMENT
>.062MM.

Fig. 4



TRANSITION ZONES
TRANSITIONAL BETWEEN 5B & 6B
TRANSITIONAL BETWEEN 4 & 6A
TRANSITIONAL BETWEEN 3 & 4
TRANSITIONAL BETWEEN 4 & DELTA-FRONT SILTY CLAYS
BIRDFOOT-ST. BERNARD PRODELTA CLAYS
EXPLANATION
1 SOUND & BAY DEPOSIT
2 MISSISSIPPI-ALABAMA BARRIER ISLAND SAND DEPOSIT
3 CHANDELEUR SAND DEPOSIT
4 ST. BERNARD PRODELTA DEPOSIT
OUTER SHELF LIME DEPOSIT
5A1 5A2 MISSISSIPPI-ALABAMA REEF & INTERREEF FACIES
5B WESTERN FLORIDA LIME-MUD FACIES
EASTERN SAND DEPOSIT
6A MISSISSIPPI-ALABAMA SAND FACIES
6B CAPE SAN BLAS SAND FACIES
UPPER CONTINENTAL SLOPE CLAYS
DELTA-FRONT SILTS
DELTA-FRONT SILTY CLAYS
MUDDY SANDS WITH PEBBLES
SHELL
MOBILE RIVER DELTA SILTS
ISLANDS OR COASTAL PROMONTORIES
SCALE
STATUTE MILES
0 10 20 30 40
90°00' 30' 89°00' 30' 88°00' 30' 87°00' 30' 86°00' 30' 85°00' 30' 84°00'
30' 31°00' 30' 30°00' 30' 29°00'
LOUISIANA
MOBILE
TOMBIGBEE R.
ALABAMA R.
MOBILE R.
TENSAW R.
GULFPORT
BILOXI
PENSACOLA
PENSACOLA BAY
CHOCTAWHATCHEE BAY
PANAMA CITY
APALACHICOLA R.
PORT ST. JOE
ALLIGATOR PT.
ST. BERNARD SUBDELTA
MISSISSIPPI R.
100 FATHOMS
DESOTO CANYON AXIS
FLORIDA SCARP
LINE 10 (FIG. 3)
GULF OF MEXICO


Fig. 5

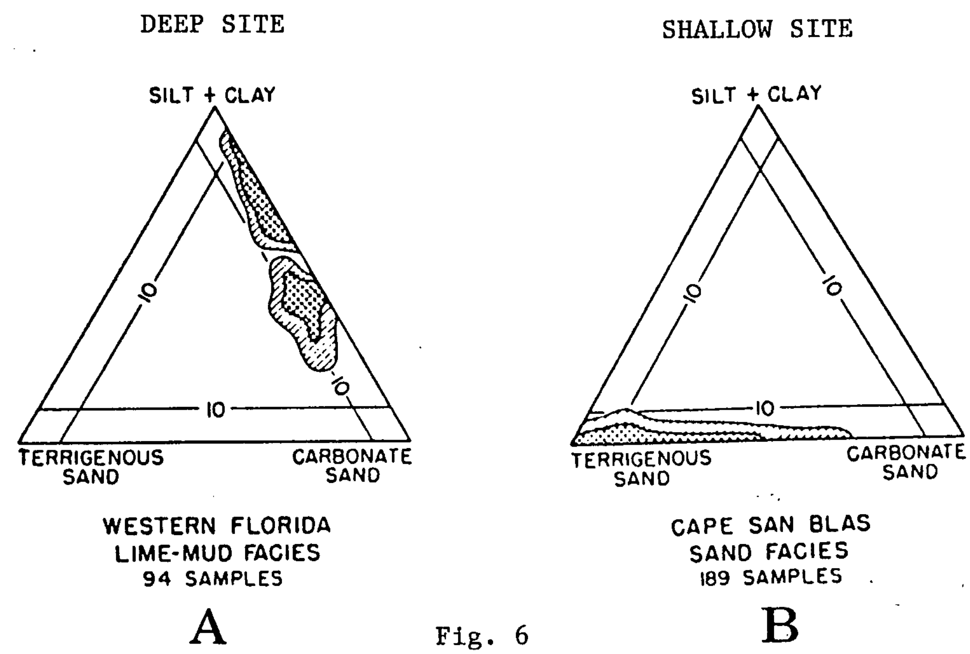

DEEP SITE
SILT + CLAY
TERRIGENOUS SAND
CARBONATE SAND
10
WESTERN FLORIDA
LIME-MUD FACIES
94 SAMPLES
A
SHALLOW SITE
SILT + CLAY
TERRIGENOUS SAND
CARBONATE SAND
10
CAPE SAN BLAS
SAND FACIES
189 SAMPLES
B

Fig. 6

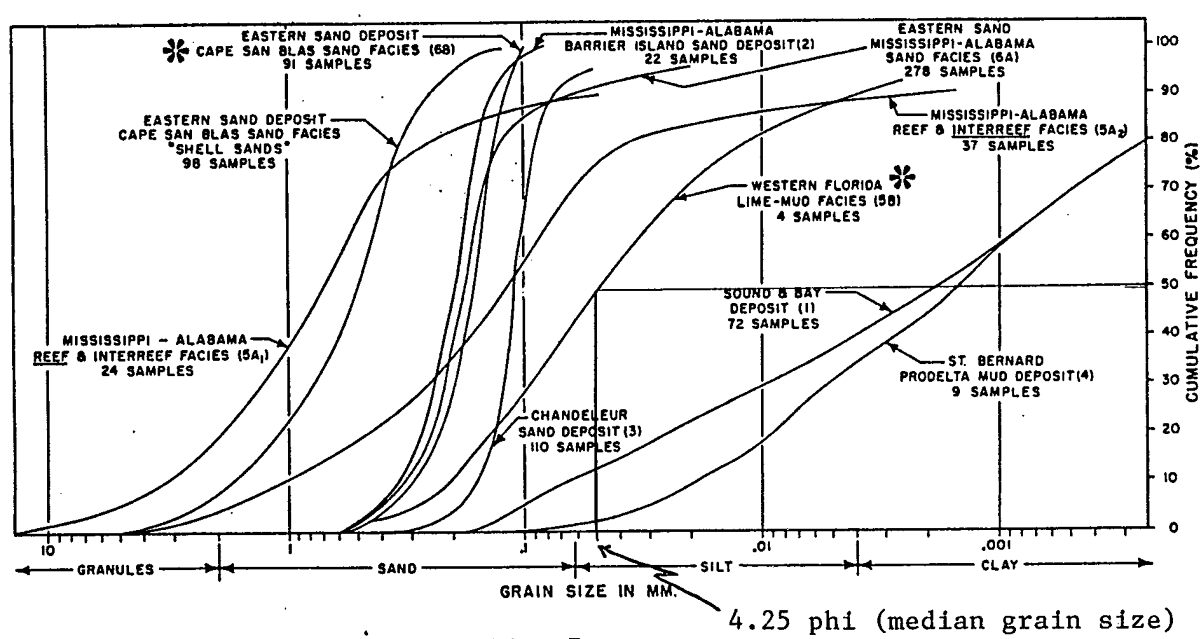
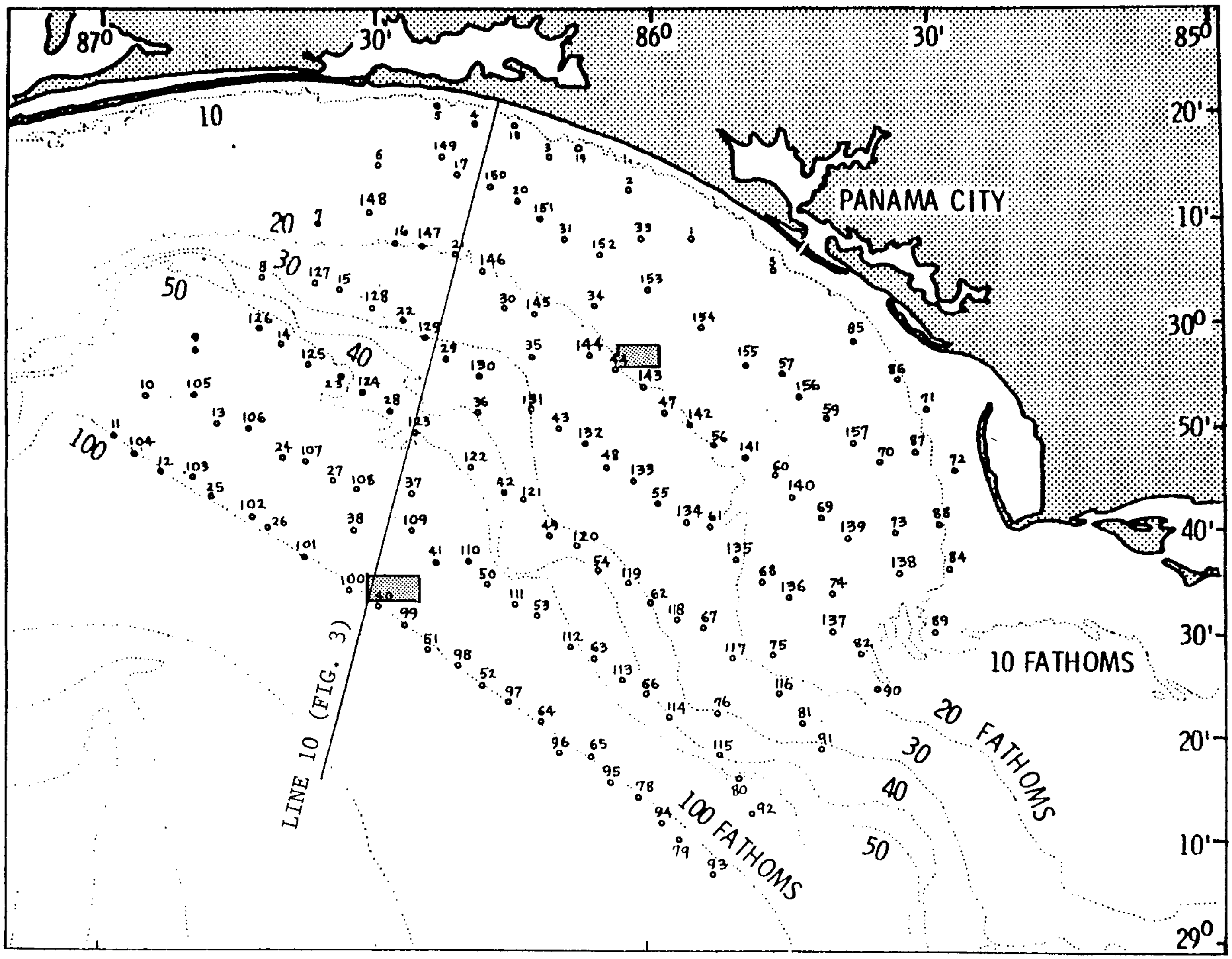
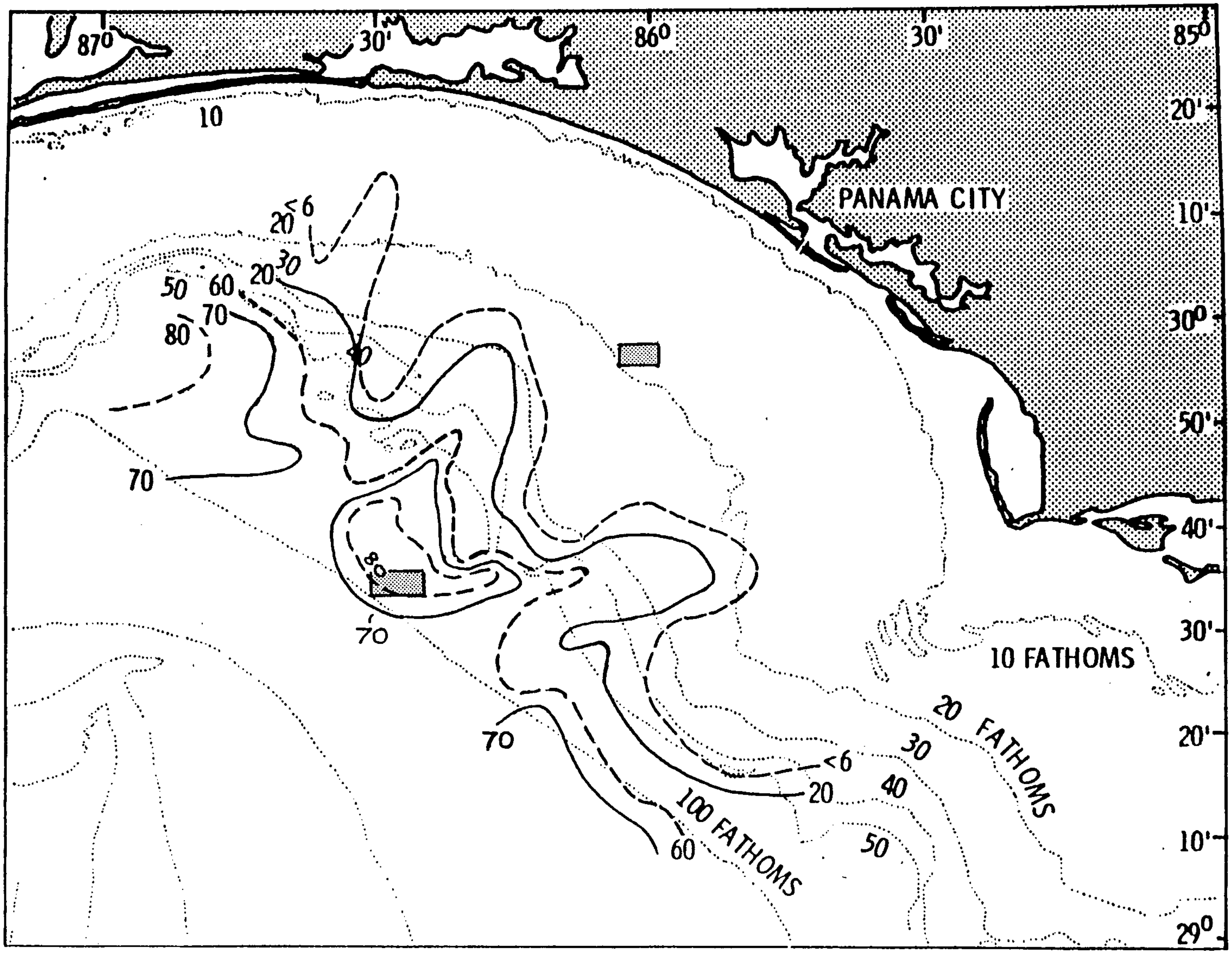

EASTERN SAND DEPOSIT
CAPE SAN BLAS SAND FACIES (68)
91 SAMPLES
EASTERN SAND DEPOSIT
CAPE SAN BLAS SAND FACIES
"SHELL SANDS"
98 SAMPLES
MISSISSIPPI-ALABAMA
BARRIER ISLAND SAND DEPOSIT(2)
22 SAMPLES
EASTERN SAND
MISSISSIPPI-ALABAMA
SAND FACIES (6A)
278 SAMPLES
MISSISSIPPI-ALABAMA
REEF & INTERREEF FACIES (5A2)
37 SAMPLES
WESTERN FLORIDA
LIME-MUD FACIES (5B)
4 SAMPLES
SOUND & BAY
DEPOSIT (1)
72 SAMPLES
ST. BERNARD
PRODELTA MUD DEPOSIT(4)
9 SAMPLES
MISSISSIPPI - ALABAMA
REEF & INTERREEF FACIES (5A1)
24 SAMPLES
CHANDELEUR
SAND DEPOSIT (3)
110 SAMPLES
CUMULATIVE FREQUENCY (%)
10
.1
.01
.001
GRANULES
SAND
SILT
CLAY
GRAIN SIZE IN MM.
4.25 phi (median grain size)

Fig. 7



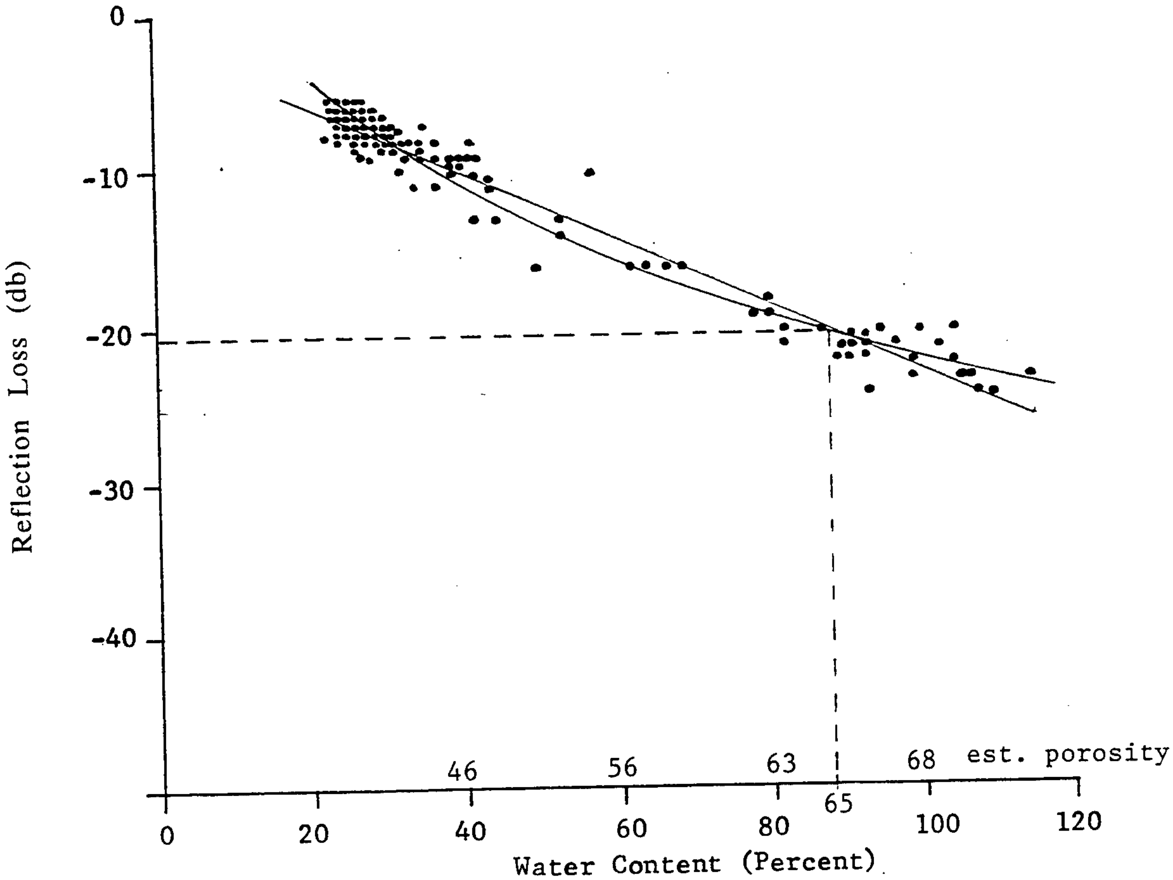
87°
30'
86°
30'
85°
20'
10'
30°
50'
40'
30'
20'
10'
29°
PANAMA CITY
10 FATHOMS
20 FATHOMS
100 FATHOMS
LINE 10 (FIG. 3)


Fig. 8



87°
30'
86°
30'
85°
20'
10'
30°
50'
40'
30'
20'
10'
29°
PANAMA CITY
10
10 FATHOMS
20 FATHOMS
100 FATHOMS
20
30
40
50
60
70
80
<6


Fig. 9



0
-10
-20
-30
-40
Reflection Loss (db)
46
56
63
68
est. porosity
65
0
20
40
60
80
100
120
Water Content (Percent)


Fig. 10

SEDIMENT CLASSIFICATION MODEL:
BOGGART v.3

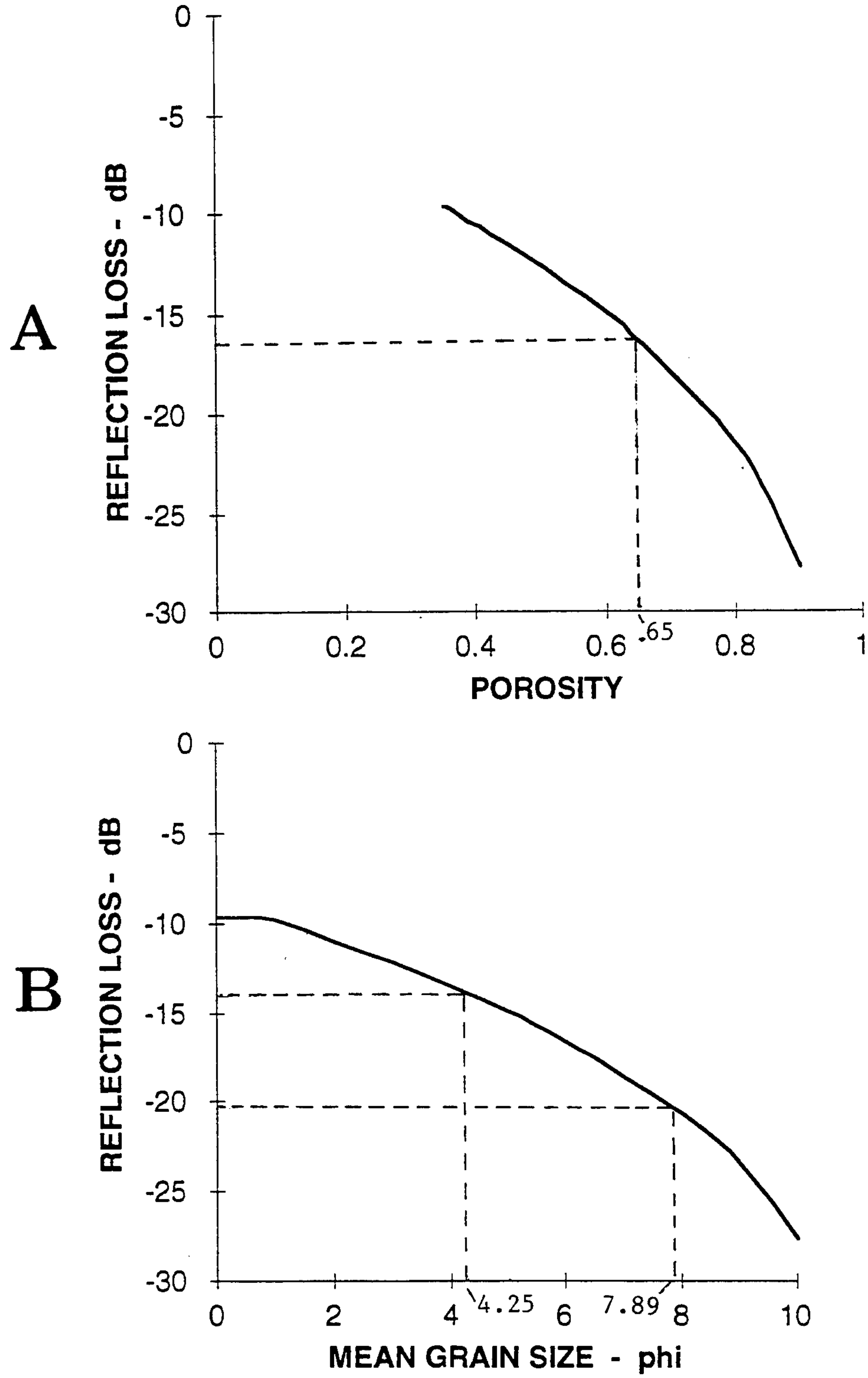



Fig. 11

# TABLE A1

## ACOUSTIC AND SEDIMENT MEASUREMENTS
(Page 2 of 5)

| Station | Water Depth (fathoms) | Average Specific Gravity of Solids | Bulk Density (g/cc) | Void Ratio (%) | Porosity (%) | Water Content (%) | Fine Fraction (%) | Sand Fraction (%) | Gravel Fraction (%) | Reflection Coefficient | Echo Length (db, ref 1 msec) | P + L = E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 40 | 2.41 | 1.65 | 127 | 56 | 53 | 49 | 48 | 4 | 0.19 | 19 | 1 |
| 37 | 35 | 2.24 | 1.52 | 202 | 64 | 90 | 75 | 24 | 0 | 0.22 | 21 | -4 |
| 38 | 80 | 1.83 | 1.33 | 171 | 63 | 93 | 81 | 18 | 1 | 0.20 | 22 | -6 |
| 39 | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 100 | 2.00 | 1.37 | 197 | 66 | 99 | 78 | 21 | 1 | 0.21 | 22 | -5 |
| 41 | 71 | 2.26 | 1.52 | 240 | 37 | 106 | 79 | 21 | 0 | 0.21 | 22 | -5 |
| 42 | 40 | 2.43 | 1.66 | 124 | 55 | 51 | 14 | 86 | 0 | 0.29 | | |
| 43 | 28 | 2.22 | 1.74 | 92 | 45 | 42 | 1 | 49 | 50 | 0.36 | 15 | 1 |
| 44 | 20 | 2.06 | 1.72 | 53 | 33 | 26 | 1 | 93 | 7 | 0.44 | 15 | 2 |
| 45 | - | - | - | - | - | - | - | - | - | | | |
| 46 | - | - | - | - | - | - | - | - | - | | | |
| 47 | 20 | 2.31 | 1.76 | 92 | 45 | 40 | 0 | 15 | 85 | 0.38 | 15 | 2 |
| 48 | 25 | - | - | - | - | - | 4 | 48 | 47 | | | |
| 49 | 31 | 2.50 | 1.93 | 85 | 42 | 34 | 43 | 55 | 2 | 0.34 | 16 | 4 |
| 50 | 60 | 2.30 | 1.48 | 227 | 69 | 99 | 81 | 18 | 1 | 0.21 | 22 | -4 |
| 51 | 100 | 2.19 | 1.55 | 252 | 67 | 115 | 68 | 31 | 1 | 0.21 | 21 | -6 |
| 52 | 100 | 2.24 | 1.43 | 208 | 68 | 93 | 67 | 29 | 3 | 0.22 | 21 | -3 |
| 53 | 70 | 2.21 | 1.55 | 177 | 61 | 80 | 54 | 45 | 1 | 0.24 | 20 | -2 |
| 54 | 35 | 2.47 | 1.60 | 154 | 61 | 62 | 58 | 42 | 1 | 0.26 | 20 | 0 |
| 55 | 25 | 2.12 | 1.74 | 72 | 39 | 34 | 3 | 58 | 39 | 0.29 | | |
| 56 | 20 | 2.52 | 1.98 | 62 | 38 | - | 1 | 95 | 4 | | | |
| 57 | 16 | 2.45 | 1.89 | 74 | 40 | 30 | 2 | 72 | 26 | 0.41 | 15 | 3 |
| 58 | - | - | - | - | - | - | - | - | - | - | | |
| 59 | 14 | 2.42 | 1.97 | 61 | 35 | 25 | 2 | 96 | 2 | 0.44 | 15 | 4 |
| 60 | 18 | 2.56 | 1.99 | 62 | 38 | 30 | 1 | 87 | 11 | 0.44 | 15 | 4 |
| 61 | 20 | 2.41 | 1.86 | 65 | 40 | 27 | 2 | 80 | 18 | 0.44 | 15 | 4 |
| 62 | 31 | 2.45 | 1.72 | 108 | 51 | 44 | 29 | 69 | 2 | 0.34 | 18 | 3 |
| 63 | 45 | 2.42 | 1.48 | 140 | 60 | 58 | 30 | 67 | 3 | | | |
| 64 | 100 | 2.35 | 1.54 | 193 | 66 | 82 | 74 | 23 | 2 | 0.22 | 21 | -3 |
| 65 | 90 | 2.12 | 1.50 | 203 | 62 | 88 | - | - | - | | | |
| 66 | 40 | 2.60 | 1.86 | 90 | 46 | 35 | 3 | 95 | 2 | 0.44 | 16 | 5 |
| 67 | 25 | 2.52 | 1.91 | 63 | 39 | 25 | 1 | 9 | 9 | 0.44 | 15 | 4 |
| 68 | 18 | 2.45 | 1.93 | 62 | 38 | 25 | 1 | 84 | 15 | 0.44 | 15 | 4 |
| 69 | 16 | 2.53 | 1.82 | 68 | 43 | 27 | 4 | 95 | 1 | 0.44 | 16 | 5 |
| 70 | 13 | 2.58 | 1.54 | 75 | 43 | 29 | 5 | 93 | 3 | 0.44 | 16 | 5 |